

## Amphibious vehicle

The present invention relates to an amphibious vehicle.

Amphibious vehicles are inherently required to carry both road vehicle and marine vessel dedicated equipment. Hence, amphibious vehicles are generally heavier than boats of a similar size and power. This is particularly true in the case of planing amphibians, which require a relatively heavy wheel streamlining mechanism, such as retractable suspension or the like. In the case of an amphibious vehicle with open wheel arches, the drag exerted by the arches can be considerable and hence the overall hull drag is greater than for a conventional boat. This additional weight and drag make it difficult for the vehicle to rise onto the plane without initial deployment of trim tabs.

Trim tabs are well known for marine vessels, and in particular planing boats, as means for controlling the trim and attitude of the vessel to compensate for changes in load, speed or sea conditions. Commonly these devices are in the form of flat tabs or planes, which are pivotably connected along a generally horizontal axis to the hull of the vessel below the waterline near the stern. The angle of orientation of the trim tabs is adjustable and hence determines the fore and aft attitude of the vessel, when it is being propelled through the water. For example, if the rear of the vessel is heavily loaded the bow will typically rise out of the water and lead to inefficient forward motion. In these circumstances the angle of the trim tabs relative to the hull can be increased to lower the bow, lift the stern, and hence get the boat back onto a plane.

The position of the trim tabs on a conventional boat, when docked, is not of great importance since it is unlikely that the tabs will come into contact with, and be damaged by a submerged obstacle. Nevertheless, since trim tabs are typically extended by means of hydraulic actuators it is generally desirable for trim tabs to be retracted, when the boat is not in use, to avoid unnecessary marine growth on the actuators. Retraction also minimises the risk of damage when a boat is lifted from the water, for example, to go into dry storage. In accordance with this US Patent No. 5, 113, 780 discloses a trim tab control system, which includes a facility for automatically retracting the trim tabs when the engine ignition is switched off.

The system described in US 5, 113, 780 is designed specifically for marine only vessels and is of limited benefit in the case of amphibious vehicles fitted with trim tabs. The greatest risk of damage, in the case of amphibious vehicles, occurs during and after the transition from marine to terrestrial mode, whilst the engine is still switched on. If the tabs remain in an operational position when the vehicle leaves the water, there is a significant risk that they may strike the ground at speed. Similarly, reversing into an obstacle with the trim tabs deployed could damage the tabs, the actuators and the body of the vehicle. The risk of inadvertently leaving the trim tabs deployed is enhanced because during the marine to terrestrial transition period the operator has several other important control tasks to consider.

- 10 Furthermore, the requirement in US 5, 113, 780 that the tabs be retracted after the ignition is switched off necessitates an ignition independent power supply for powering the retraction system. Such a supply, however, is undesirable because the power source remains permanently connected to the circuit that it powers. Hence, even a relatively small current drain from the retraction circuit could lead to a significant reduction in the life of the source.
- 15 Whilst a permanent current drain may be unlikely to arise as a result of poor design there is a significant probability that it could occur as a result of malfunction. The risk of this is particularly high in marine vessels where the presence of water makes short circuits more likely. It will also be appreciated that short circuits of this type also constitute a safety hazard.

This latter problem has been tackled in US 5, 474, 013, which describes a system for automatically retracting trim tabs on a boat independently of the operation of the ignition switch. In the system described, a capacitor is charged from the vessels battery and the charge stored can be discharged to fully retract the trim tabs. However, this system is also designed specifically for marine only vessels and again is of limited benefit in the case of amphibious vehicles, for the reasons discussed above in relation to US 5, 113, 780.

- 25 There is, therefore, a need for an amphibious vehicle, which includes a trim tab deployment system to allow it to rise onto the plane. There is also a need for the trim tab system for the amphibious vehicle to overcome or at least to mitigate the problems referred to above.

According to one aspect of the present invention there is provided an amphibious vehicle adapted for use on land and on water including a vehicle body, and at least one trim tab, for adjusting the trim of the amphibious vehicle when it is in a marine mode, connected to the vehicle body and movable relative to the vehicle body between a retracted position and any  
5 one of a range of operational positions, and a control system for controlling the position of the or each trim tab including detecting means for detecting at least one mode change event and tab actuation means for moving the or each trim tab relative to the vehicle body, the control system being adapted to automatically move the or each trim tab either into the retracted position or into any one of a range of operational positions according to the mode  
10 change event detected.

Preferably, the mode change event, detectable by the detecting means, is a first mode change event indicative of an onset of transition into a marine mode from a terrestrial mode and the control system is adapted to automatically move the or each trim tab into one of a range of operational positions on detection of said first mode change event.

15 Preferably the or a further mode change event, detectable by the detecting means, is a second mode change event indicative of an onset of a transition into the terrestrial mode from a marine mode and the control system is adapted to automatically move the or each trim tab into the retracted position on detection of said second mode change event.

Preferably the detecting means are also capable of detecting selection of reverse propulsion in  
20 a marine mode, and the control system is adapted to automatically move the or each trim tab into the retracted position on detection of the selection of reverse propulsion.

Preferably the detecting means are also capable of detecting a selection of forward propulsion when the vehicle is moving in the reverse direction in a marine mode and the control system is adapted to automatically move the or each trim tab into any one of a range of operational  
25 positions on the selection of forward propulsion.

Preferably the control system includes means for signalling an operator on detection of at least one event.

Preferably the vehicle has a set of wheels for supporting the vehicle when it is in terrestrial mode, and the control system further includes means for retracting the set of wheels on detection of a transition into marine mode and means for deploying the set of wheels on detection of a transition into terrestrial mode.

- 5 Preferably the vehicle has a jet drive for propelling the vehicle when it is in marine mode and a reversing bucket, and the control system includes means for deploying the reversing bucket on detection of selection of reverse propulsion. Alternatively, where a reversing bucket is not fitted, the jet drive may be driven in reverse through the vehicle transmission.

- 10 According to another aspect of the present invention there is provided a method for controlling a trim tab system for an amphibious vehicle including the steps of automatically detecting a mode change event, and on detection of the mode change event automatically moving the or each trim tab either into the retracted position or into any one of a range of operational positions according to the event detected.

Preferably the mode change event detected is an onset of transition into a terrestrial mode.

- 15 Preferably the mode change event detected is an onset of transition into a marine mode.

An embodiment of the invention will now be described, by way of example only, with reference to the following drawings in which:

Figure 1 shows diagrammatically a simplified side view, partially cut away, of an amphibious vehicle according to the invention;

- 20 Figure 2 shows diagrammatically a simplified plan view, from beneath, of the amphibious vehicle of figure 1;

Figure 3 is a functional block diagram of part of an integrated control network for the amphibious vehicle of figure 1;

Figure 4 shows a control system logic sequence to initiate a mode change;

Figure 5 shows a control system logic sequence for a mode change from terrestrial to marine mode, as initiated by the sequence shown in figure 4; and

Figure 6 shows a control system logic sequence for a mode change from marine to terrestrial mode, as initiated by the sequence shown in figure 4.

5 In figures 1 and 2 an amphibious vehicle is designated generally 10 and a trim tab system is designated generally 12. The amphibious vehicle 10 is capable of operation in both a terrestrial mode, for travel on land, and a marine mode, for travel on water. The vehicle 10 includes a vehicle body 14 having a hull section 16 and an outer body section 18. The hull section 16 is equivalent to the hull of a conventional boat and includes a transom 20 at the  
10 stern.

The trim tab system 12 includes two tabs 22 and two hydraulic actuators 26, provided one on either side of a central longitudinal axis AA' of the vehicle 10 as seen in figure 2. Whilst the figures show hydraulic actuators, any suitable actuation means may be used, for example electrically powered actuators. Each of the tabs 22 is connected to the base of the transom 20  
15 by a corresponding hinge 24 along a generally horizontal axis to allow independent rotational movement of each tab relative to the transom 20, as seen on figure 1.

The hydraulic actuators 26 are of conventional construction, each actuator 26 having a cylinder 28 into which one end of an actuator rod 30 is slidably received. The cylinder 28, of each hydraulic actuator 26, is mounted pivotally on the transom 20 above a corresponding tab  
20 22 to which the protruding end of the actuator rod 30 is pivotally connected. Hence, in operation, extension and retraction of the actuator rod 30 lowers and raises the corresponding tab 22 respectively.

The amphibious vehicle 10 has the standard features associated with a road vehicle including transmission, suspension and a set of wheels 32. The wheels 32 are provided with a retraction  
25 mechanism, which can be used to retract the wheels 32 from a protracted position 31 during a transition into marine mode. Similarly, the retraction mechanism can be used to protract the wheels 32 from a retracted position 33 during a transition into terrestrial mode. As shown in

figure 3, the retraction mechanism makes up part of a mode change system 54 for converting the amphibious vehicle 10 from marine mode to terrestrial mode and vice versa.

The retraction mechanism may comprise any suitable means for retracting and protracting the wheels 32. Preferably, however, the retraction mechanism is of the form described in  
5 European Patent No. 0742761. The retraction mechanism, as such, does not form part of the present invention and so will not be described here in detail. However, if the reader requires details of the operation and construction of a suitable retraction system then they should refer to EP 0742761, the contents of which are hereby incorporated by reference.

The suspension may be a conventional hydro-pneumatic system with suspension cylinders  
10 part filled with hydraulic fluid and part filled with pneumatic gas. Prior to road use, the suspension cylinders of the amphibious vehicle require charging to bring the vehicle to the correct road height. Typically, the charging will occur either when the vehicle engine is switched on in terrestrial mode or when the vehicle makes a transition from marine into terrestrial mode. It should be understood, however, that the vehicle may have any suitable  
15 suspension system.

Additionally, the amphibious vehicle 10 includes a marine drive 34 for providing propulsion when the vehicle 10 is in the marine mode. The marine drive 34 is a conventional jet drive, which in operation issues a jet of high pressure water to propel the vehicle 10 forward. The jet drive may be fitted with a reversing bucket 36, which in use, may be deployed to divert the  
20 direction of the water jet to propel the vehicle 10 in reverse. Alternatively, where a reversing bucket is not fitted, the direction of rotation of the jet drive may be reversed through the vehicle transmission. It will be appreciated that other forms of marine drive could be employed, with corresponding reversing mechanisms, such as a marine propeller for example.

25 The mode change system 54 also includes means for decoupling the road wheel transmission and optionally engaging the marine drive 34 during transition into marine mode and means for charging the suspension, coupling the road wheel transmission and optionally disengaging the marine drive 34 during transition into terrestrial mode.

Referring now to figure 3, the trim tab system 12 also includes an electro-hydraulic system 40 for independently extending and retracting the rods 30 and hence operating the tabs 22. The electro-hydraulic system 40 includes an electric motor 42, which in operation, drives a fluid pump 44 to move fluid under pressure, via flow control valves 46, either to or from the actuators 26, to extend or retract the actuator rods 30 respectively. The flow control valves 46 allow independent selection and control of the actuators 26. Alternatively, the system for independently extending and retracting the rods 30 could be purely electro-mechanical employing electric motors to operate mechanical actuators with no hydraulic parts.

In order to control the electro-hydraulic and electro-mechanical systems an integrated control network 50 is provided. The control network 50 has a main controller 52, a set of input subsystems 56, and a set of output subsystems 58. The main controller 52 comprises a set of control subsystems 60, 62, 64, which include a propulsion controller 60, a mode change controller 62 and a trim tab controller 64. The main controller 52 can be implemented using any suitable means such as a dedicated logic circuit or a pre-programmed micro-controller.

The input subsystems 56 include manually operated switches such as a reverse selector 66, a mode change switch 68 and manual trim tab control switches 70. The input subsystems 56 also include sensor means comprising suspension droop sensor apparatus 74, for determining if the water buoyantly supports the vehicle 10. The sensor system may comprise any suitable means for detecting when the vehicle 10 is in water and buoyantly supported by it. An amphibious vehicle incorporating suitable sensor means is described in the applicant's International patent application number PCT/GB2002/005359 that claims the benefit of priority from British application No. 0128338.1, the contents of which are hereby incorporated by reference. A water presence sensor 72 may also be provided, as a secondary sensor.

The output subsystems 58 include the mode change system 54, the trim tab system 12, a reversal system 76 and warning systems 48, 78.

In operation, the main controller 52 accepts external inputs from the input subsystems 56 and directs them to at least one of the control subsystems 60, 62, 64 for processing. The control

subsystems 60, 62, 64, process the inputs and produce a corresponding set of outputs, which determine, and hence control, the behaviour of the output subsystems 58. The outputs from any control subsystem 60, 62, 64, can also form internal inputs to any other control subsystem 60, 62, 64.

- 5 As seen in figure 3 the trim tab controller 64 receives external inputs from the trim tab control switches 70 and the reverse selector 66, and an internal input from the mode change controller 62. The trim tab controller 64 produces a corresponding set of outputs for controlling the trim tab system. More specifically the trim tab controller 64 controls the motor 42, the pump 44, the flow control valves 46 and hence the relative positioning of the  
10 tabs 22. The trim tab controller 64 also controls a trim tab warning system 48 for alerting the vehicle operator, when appropriate, to the position of the trim tabs 22.

The reverse selector 66 also provides an external input to the propulsion controller 60, which in turn produces an output to the reversal system 76 for either deploying or retracting the reversing bucket 36; or alternatively to reverse the rotation direction of the vehicle  
15 transmission.

The mode change controller 62 receives external inputs from the mode change switch 68, the suspension droop sensor 74 and the water presence sensor 72. The mode change controller 62 processes these external inputs and produces outputs to the mode change system 54, a mode change warning system 78, the propulsion controller 60 and trim tab controller 64.

- 20 The mode change warning system 78 includes a visual warning device in the form of a warning light to alert the operator when the vehicle is undergoing a mode change and to inform the operator when the transition is complete. The mode change warning system 78 also includes an audible warning device in the form of a buzzer for warning people in the vicinity of the vehicle 10 when a mode change is imminent.

- 25 It will be appreciated that the some or all of the systems and subsystems making up the control network 50 may be equipped with reset functions (not shown) for resetting the whole system or individual systems if required, for example, in the event of problems during mode



changes.

In operation, the control system 50 follows the logic sequences shown in figures 4 and 5 to affect a transition from terrestrial into marine mode and the logic sequences shown in figures 4 and 6 to affect a transition from marine into terrestrial mode. The logic sequences include  
5 several mode change events interspersed with decision points. Mode change events are events that are associated with transition either to terrestrial mode or to marine mode.

In figure 4 a control system logic sequence to initiate a mode change is designated generally 90. While the vehicle 10 is operational, the mode change controller 62 monitors the status of the mode change switch 68 to determine if it has been activated. On activation of the mode  
10 change switch 68, the logic sequence 90 initially establishes whether the switch has been activated in error. If the switch 68 is activated for less than three seconds then this is deemed to be indicative of accidental operation, for example by an operator pressing the wrong switch. Hence, no further action is taken and the mode change controller 62 reverts to its monitoring activity.

15 If the switch 68 is activated for more than three seconds then the mode change controller goes on to establish if the switch 68 is released within ten seconds. If the switch 68 remains activated after ten seconds then this is deemed to be indicative of malfunction or an enduring accidental operation, for example by an object being placed on or against the switch 68. Hence, no further action is taken and the mode change controller 62 reverts to its monitoring  
20 activity. An alert system could also be included which warns the operator that the switch 68 has either been erroneously operated or is malfunctioning.

Thus, if the duration of the switch activation is between three and ten seconds the mode change controller 62 signals the mode change warning system 78 to flash the visual warning device and sound the audible warning device, prior to determining the current status of the  
25 vehicle and initiating an appropriate mode change logic sequence.

In figure 5 a control system logic sequence for a mode change from terrestrial to marine mode is designated generally 100. On initiation, the mode change controller 62 monitors the

external inputs from the sensor subsystem to determine if conditions are suitable for transition to occur. If the external input to the controller 62, from the suspension droop sensor apparatus 74 indicates that the vehicle 10 is not buoyantly supported, sufficient to allow safe retraction of the wheels 32, no action is taken and monitoring continues. However, if the suspension droop sensor apparatus 74 indicates that safe retraction of the wheels 32 is possible, the mode change controller 62 goes on to test for external water presence by monitoring the external input received from the water presence sensor 72. When external water presence is confirmed the vehicle 10 is deemed to be in water. If full droop and/or water presence are not detected within thirty seconds then conversion is stopped and the control system reverts to its general monitoring mode.

At this stage a system check is carried out and any faults detected result in termination of the process. If no faults are detected then the transition to marine mode can begin.

Transition to marine mode involves the mode change controller 62 initiating a number of mode change events 108, 110, 112, 114. In accordance with this, outputs are produced for controlling the mode change system 54, the mode change warning system 78, and for further processing by the trim tab controller 64 and the propulsion controller 60.

The mode change controller 62 signals the mode change system 54 to retract the wheels 32 and to decouple the road wheel transmission of the vehicle 10. Similarly, where a marine drive decoupler is fitted, the propulsion controller 60 receives an internal input from the mode change controller 62 and makes a subsequent output to the mode change system 54 to engage the marine drive 34. After this has occurred the mode change controller 62 signals the mode change warning system 78 to switch the visual warning device from flashing to continuous and the audible warning device to silent.

Additionally, on receipt of the internal input from the mode change controller 62 the trim tab controller 64 signals the trim tab system to automatically deploy the trim tabs from a retracted position 80 into a marine ready position 82. As seen on figure 1 the retracted position 80 lies at an angle substantially  $13^\circ$  above the horizontal and the marine ready position 82 lies substantially at an angle between  $9^\circ$  and  $12^\circ$  below the horizontal.

At this stage the mode change controller 62 interacts with the mode change system to establish when the wheels 32 are retracted. Once the wheels 32 are retracted the vehicle is ready for planing. However, full engine power can be applied as soon as the road wheel drive is disengaged.

- 5    Whilst figure 5 shows the mode change events 108, 110, 112, 114 occurring sequentially it will be appreciated that there are other sequences that may be followed and some or all of the events 108, 110, 112, 114 may run concurrently to speed up the transition.

In figure 6 a control system logic sequence for a mode change from marine to terrestrial mode is designated generally 120. Initially a system check is carried out and any faults detected  
10    result in termination of the process. If no faults are detected then the transition to terrestrial mode can begin.

As with the transition to marine mode, the transition to terrestrial mode involves the mode change controller 62 initiating a number of mode change events 124, 128, 130, 132, 134. In accordance with this, outputs are produced for controlling the mode change system 54, the  
15    mode change warning system 78, and for further processing by the trim tab controller 64 and the propulsion controller 60.

The mode change controller 62 signals the mode change system 54 to protract the wheels 32 and then suspends further commands until the suspension droop sensor 74 indicates that the suspension has reached full travel. The mode change controller 62 then signals the mode  
20    change system 54 to charge the suspension and couple the transmission ready for road use. Similarly, where a marine drive decoupler is fitted, the propulsion controller 60 receives an internal input from the mode change controller 62 and makes a subsequent output to the mode change system 54 to disengage the marine drive 34.

Additionally, on receipt of an internal input from the mode change controller 62 the trim tab  
25    controller 64 signals the trim tab system to automatically move the trim tabs to the retracted position 80 from any one of a range of operational positions. After retraction has occurred the mode change controller 62 signals the mode change warning system 78 to switch the visual

warning device from flashing to off and the audible warning device to silent.

Whilst figure 6 shows the mode change events 124, 128, 130, 132, 134 occurring sequentially it will be appreciated that there are other sequences that may be followed and some or all of the events 124, 128, 130, 132, 134 may run concurrently to speed up the transition.

- 5 When the vehicle 10 is operating in the marine mode the operator can use the trim tab control switches 70 to manually adjust the position of the trim tabs 22 depending on external conditions, the forward speed of the vehicle 10, vehicle loading and any other requirements. In use, the trim tab control switches 70 provide an external input to the trim tab controller 64. The trim tab controller 64 processes this external input and makes a resulting output to the
- 10 trim tab system 12 to either increase or decrease the angle of the tabs 22. For example, when the vehicle begins motion under forward propulsion the operator will typically increase the angle of the tabs from the marine ready position to an operational position. As the vehicle 10 accelerates and the bow begins to rise, the operator can further increase the angle of the tabs to correct fore and aft attitude. Similarly, if the vehicle 10 is unevenly loaded, such that it lists
- 15 to one side, the tabs 22 may be operated independently to correct the port / starboard attitude of the vehicle 10 when it is in motion.

- It will be appreciated that much of the manual tab control can be further automated to take account of standard conditions and loading. For example, the trim tab controller 64 could be provided with internal inputs from the propulsion controller 60 to automatically adjust the
- 20 tabs depending on speed. Alternatively, a separate speed sensor could be used. A feedback mechanism involving a gyroscope, yaw rate sensor, or other attitude detector could also be included, which would allow automatic adjustment of the tabs depending on the attitude of the vehicle. Tab position feedback, to controller 64, would be required for fully automatic trim tab control.

- 25 When the vehicle 10 is operating in the marine mode, under forward propulsion, and reverse propulsion is then selected, the reverse selector 66 provides external inputs, corresponding to reverse selection, to the trim tab and propulsion controllers 64, 60. Consequently, the external inputs are processed by the appropriate control subsystem 60, 64 and appropriate outputs

made to the related output subsystems 12, 76. Specifically, the trim tab controller 64 makes outputs to the trim tab system 12 to move the tabs 22 to the retracted position 80, and the propulsion controller 60 makes an output to the reversal system 76 to initiate the deployment of the reversing bucket 36.

- 5     Conversely, when the vehicle 10 is operating in the marine mode, under reverse propulsion, and forward propulsion is then selected, the reverse selector 66 provides external inputs, corresponding to forward selection, to the trim tab and propulsion controllers 64, 60. In this case, after processing the external input, the propulsion controller 60 initiates the retraction of the reversing bucket 36, where fitted, by the reversal system 76. Correspondingly, the trim tab  
10     controller 64 initiates the deployment of the tabs 22, to the marine ready position 82, by the trim tab system 12.

- It will be appreciated that the control system 50 may also be configured to respond to other events, such as engine ignition being switched on or off. For example, when the vehicle 10 is in the marine mode with the engine off, and the ignition is then switched on, external inputs  
15     may be provided to the trim tab controller 64 to move the tabs 22 to the marine ready position 82. Similarly, when the engine is switched off external inputs may be provided to the trim tab controller 64 to fully retract the tabs 22 or to move them to any other suitable default position.

- Whereas the invention has been described in relation to what is presently considered to be the  
20     most practical and preferred embodiments, it is to be understood that the invention is not limited to the disclosed arrangements but rather is intended to cover various modifications and equivalent constructions included within the spirit and scope of the invention.